



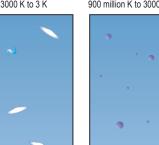
Cosmic Chemistry: Cosmogony

Thought Experiments: Tracing Origins

STUDENT HANDOUT

Epoch 8 - Matter condenses: Galaxies, stars planets and life develop

3000 K to 3 K



Late in the epoch, quarks and electrons are found in H and He atoms



Early in the epoch, quarks made up H and He nuclei and electrons are separate particles.

300,000 years to 30 minutes

Epoch 7- Atoms are formed from protons, neutrons. and electrons as

900 million K to 3000 K

nuclei and electrons temperature decreases

900 million K

Epoch 6 - Atomic



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(Quarks make up protons and neutrons in the free nuclei. The universe is 87% protons (with equal numbers of electrons) and 13% neutrons.

30 minutes to 100 seconds

Epoch 5 - Neutron

1 billion K

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decay

 \bigcirc \rightarrow \bigcirc

At beginning of this

number of neutrons

so same number of

down quarks exist.

As neutrons decay

into protons, there

than down quarks.

100 seconds to

10⁻³ seconds

are more up quarks

epoch, number of

protons equals

up quarks and

Epoch 4 - Quarks are free

10¹⁵ K

(II)

(1)

Up and down

aluons exist as

10⁻³ seconds to

10⁻⁶ seconds

free particles.

quarks and

(1)

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Epoch 3 - Quarks are hot!

10²⁸ K to 10¹⁴ K

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Hot plasma is

made primarily

electrons, and

photons.

of quarks, gluons,

 10^{-6} seconds to

10⁻³³ seconds

n

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(1)

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Epoch 2 - Quarks and anti-quarks dominate

>10³² K

Epoch 1 - The

???

10⁻⁴³ seconds

Mysterious

Epoch

10³² K to 10²⁸ K

(1) (1)

into quarks and antiquarks.

 $X \rightarrow 0 0$

X particles decay

 10^{-33} seconds to 10^{-43} seconds

Quarks and electrons are found in atoms of superstructures in all parts of the

universe.

Time -

to 300,000 years

15 billion years

15 billion years